National Aeronautics and Space Administration

Office of Space Science

NASA Sun-Solar System Connection Strategic Roadmap Advisory Committee Meeting Summary

February 10 – 11, 2005

Washington, DC

MEETING REPORT

Barbara Giles Designated Federal Official	Alphonso Diaz Co-Chair
Franco Einaudi Co-Chair	Timothy Killeen Co-Chair

Day 1 – February 10, 2005

Opening: Welcome and Introduction of Committee Members

Al Diaz, Tim Killeen, Franco Einaudi (absent), Co-Chairs

Mr. Diaz convened the meeting at 8:30 am, thanking Barbara Giles, Mission Directorate Coordinator and the Designated Federal Official (DFO) for the Sun-Solar System Connection Strategic Roadmap Advisory Committee (SSSC Strategic Roadmap Committee). He welcomed Committee members and acknowledged co-chairs Tim Killeen, National Center for Atmospheric Research, and Franco Einaudi, NASA Goddard Space Flight Center. Committee members and ex officio and liaison members conducted self-introductions (see Appendix A for a full list of Committee, ex officio and liaison members and mailing addresses). Those in attendance on Day 1 are listed below:

Charter of the SSSC Strategic Roadmap Committee:

Purpose and Duties:

1. The Committee shall draw upon the expertise of its members and other sources to provide advice and recommendations to NASA on exploring the Sun-Earth system to understand the Sun and its effects on Earth, the solar system, and the space environmental conditions that will be experienced by human explorers. Recommendations, to be provided by the Committee, will help guide Agency program prioritization, budget formulation, facilities and human capital planning, and technology investment.
2. The Committee shall function solely as an advisory body and will comply fully with the provisions of the Federal Advisory Committee Act (FACA).
3. The Committee reports to the Associate Deputy Administrator for Systems Integration and to the Administrator.

Strategic Roadmap Committee Members

Al Diaz, NASA Science Mission Directorate, co-chair
Tim Killeen, National Center for Atmospheric Research, co-chair
Scott Denning, Colorado State University
Jeffrey Forbes, University of Colorado
William C. Gibson, Southwest Research Institute
Donald Hassler, Southwest Research Institute
Todd Hoeksema, Stanford University
Craig Kletzing, University of Iowa
Victor Pizzo, National Oceanic and Atmospheric Administration
James Russell, Hampton University
James Slavin, NASA GSFC
Michelle Thomsen, Los Alamos National Laboratory
Warren Wiscombe, NASA GSFC

Barbara Giles, Mission Directorate Coordinator, DFO
Azita Valina, Advanced Planning and Integration Office (APIO) Coordinator

Ex Officio and Liaison Members

Richard Fisher, NASA Science Mission Directorate
Michael Wargo, NASA Exploration Mission Directorate
Mark Wyland, NASA Johnson Space Center;
Rosamond Kinzler, American Museum of Natural History, Liaison with Education Strategic Roadmap Committee

Others

Thomas Moore, NASA GSFC
Tim Van Sant, NASA GSFC
Jennifer Elcano, Infonetic
Craig J. Pollock, NASA HQ
Robert Connerton, NASA GSFC
Bob Lebair, NASA GSFC
Robert Hoffman, NASA GSFC
Mary Mallott, NASA HQ
T. Jens Feeley, NASA HQ
Meredith McKay, NASA HQ
Stacey Edgington, NASA HQ
Gregory K. Dees, NASA HQ
Jack Kaye, NASA HQ
Rachel Weintraub, NASA GSFC
Paul Hertz, NASA HQ
Jim Spann, NASA MSFC
John Azzolini, NASA GSFC
Rebecca Gilchrist, NASA HQ
Gordon Johnston, NASA HQ
Bridget Glynn, Lewis Burke Association
Diane Rausch, NASA HQ
Phil Richards, NASA HQ
Eric Christian, NASA HQ

Appendix B contains the agendas for both conference days.

Overview of SSSC Roadmap and Purpose of Committee

Marc S. Allen and Committee

Marc Allen, APIO, briefed the SSSC Strategic Roadmap Committee, setting the context for its efforts and recognizing NASA Strategic Objective 15 as a discrete objective for this Committee. Dr. Allen's presentation covered NASA strategic roadmaps, how they relate to larger agency goals, and how they will be used. He briefly discussed what the roadmaps should contain and provided preliminary target dates for key milestones.

To achieve basic uniformity in the scope and treatment of Roadmaps, and to have some degree of compatibility among Roadmap products, NASA has consolidated into 13 Strategic Roadmaps the actionable topic areas for responding to 18 Strategic Objectives.

NASA's definition of "Strategic Roadmap" is as follows: A coordinated and comprehensive longitudinal strategy that identifies key objectives and time-phased implementation elements, potential achievements, priorities and options, and decision points and criteria.

> NASA Strategic Objective #15
>
> Explore the Sun-Earth system to understand the Sun and its effects on Earth, the solar system, and the space environmental conditions that will be experienced by human explorers, and demonstrate technologies that can improve future operational systems.

The SSSC Strategic Roadmap Committee's objective also aligns with several of NASA's five Guiding National Objectives, including Objective 2—to extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations. National Objective 5 also directly addresses the vision for space exploration—to study the Earth system from space and develop new space-based and related capabilities for this purpose. Further, the SSSC program supports National Objective 4 by promoting international cooperation, an important point.

NASA's transformation of its strategic planning process includes forming a Strategic Planning Council (SPC), a "last stop" where decisions are made. A new Advanced Planning and Integration Office coordinates development of strategies, roadmaps, and new initiatives, working with Mission Directorates and external advisory groups. The purpose of Roadmapping, Dr. Allen explained, it is to support creation of the NASA Integrated Strategic Architecture (ISA). The 13 Roadmaps are closely related to one another and must be assembled into a "single story" and distilled into a plan that can be used by the SPC for essential agency decision-making and for budget requests. Achievement of this goal becomes more feasible with a new strategic planning process that allows for integration, previously missing when separate product lines were sent forward in their own silos. Each Strategic Roadmap Committee has a project manager and project scientist to ensure that the integration process is carried out, including the integration of Agency objectives.

Integration challenges demand that the integration process be begun early—that is, while developing the Roadmap itself. Dr. Allen stressed that relationships to potential future programs identified by other groups will be key, and that various pieces will need to "flow up" into certain identified activities. "Budget is a factor, too," he added.

Follow-On Discussion

Mr. Diaz's response is transcribed below:

> "For our second meeting, you are going to want to ask for presentations about various activity elements, so that you can put together a coherent plan. Also, it would not be very useful to leave the budget question totally unconstrained, because, in the end, to make decisions, we are going to have to understand the budgetary implications of various scenarios. If you believe that this is not an academic exercise, and I want to assure you that I do not believe that, then you must believe that someplace it connects with what is important relative to the future, which is in the budget process. . . . The upcoming budget process will happen in the post-April 15 timeframe—so somehow we need to figure out how to make our mark as a group on that process. Where do we need to lay down markers**? I think for this Committee, the relevance of this discipline to the ultimate human exploration of Mars has got to be one of the most important messages that can be sent.** In the near term, we will need to specify detail; in the mid-term, we have to have some sense of where this is going; and in the long term, we will need to understand how it connects to other things."

Tim Killeen agreed that specifying what works in the near term might be useful, but that a 30-year vision should not emphasize technological constraints or be "confined" by today's technology (look where we were 30 years ago!). Dr. Allen added that it is still necessary to start investing now in enabling technology; for example, robotic exploration required an investment in landing capability technology in order to go forward. Mr. Diaz urged members to anticipate connections: "Where are the threads, where is the continuity, where are the discontinuities, and where are the disrupting technologies that will enable something different to happen? If we can anticipate those," he said, "it may lead us to the conclusion that we need a new investment strategy in technologies in certain areas, but it will not lead us to a time-sequenced generation of technologies." The bottom line is the need for the SSSC Strategic Roadmap Committee to figure out how to invest in the future as opposed to "consume currently."

In discussing essential Roadmap elements, Dr. Allen said the front end of the report should define the SSSC program and include required capabilities mapped to decision points. In line with an integrated architecture, Todd Hoeksema, Stanford University and chair of the SSSC Foundation Roadmap Committee, urged inclusion of a decision table to capture the key decisions that will need to be made at key leadership levels, including information on how to make those decisions in a strategic way.

Dr. Allen encouraged the Committee to lay out what may be needed for other Roadmaps and to identify relationships, dependencies, and sequences to iterate with other Roadmap teams. The Committee should begin to synthesize architectural options, tempered by capabilities and agency guidance (i.e., policy, budget, and priorities). To the question of budget, he said the framework was yet unknown, but that he would work to bring forward more budgetary information. Further, while there are yet few drivers from a scheduling standpoint, a thorough airing of the interconnections between initiatives may result in negotiation to achieve a consistent program that makes sense.

The current schedule is targeting April 15, 2005, for completion of a preliminary draft and of feedback to the other Roadmap groups. Mr. Diaz urged all to work as efficiently as possible in the tight timeframe they have (see milestones table below). The first draft will be an assemblage of presentation slides plus notes, much less formal than the ultimate product but providing enough substance to convey the ideas involved.

Key Milestone	Target Dates
SPC approval of planning	August 2004
FACA charters in place	December
Complete Committee formation	December 2004/January 2005
Initial Committee meetings; integration begins	January/February
Mid-term status reviews	March
Drafts (PPT charts + notes) for internal review	April 15
First synthesis workshop	Late April
Roadmaps submitted for NRC review	June 1
Second synthesis workshop	Late June
National Research Council reviews complete	August 1
Integrated Strategic Architecture complete	October 1

The National Research Council (NRC) will review the individual Roadmaps as they near completion, and either NRC or the NASA Advisory Council (NAC) will review the Integrated Space Architecture when completed. The NRC's review will evaluate Roadmaps according to the following:

- Provision of clear and comprehensive support to the 2005 Agency Objectives
- Intrinsic merit of the derived objectives and proposed implementing programs
- Resilience with regard to changing technological capabilities
- Identification of crosscutting opportunities
- Degree of realism with regard to necessary resources, technologies, and facilities
- Treatment and realism of timelines and relationship between program elements

Recognizing that the charter for the NRC is "broad and far-reaching," Dr. Allen said new, "custom-made" groups would be formed to conduct the NRC reviews.

Sun-Solar System Connections Foundation Roadmap

Todd Hoeksema and Team

Dr. Hoeksema, reporting as the Chair of the Sun-Solar System Connections Foundation Roadmap team, said his team took a top-down approach to the SSSC Foundation Roadmap, emphasizing transformational science while also taking into account existing program priorities. The approach includes a clear rationale for priorities and strategies, with measurements and missions traceable to original objectives. Key technology needs are also identified.

Dr. Hoeksema said the SSSC Foundation Roadmap Committee's goal is to serve the present Committee, such that information is "fed up" the line and integrated by the SSSC Strategic Roadmap Committee. The key issue will be discerning how to best work together.

Discussion about the Foundation Roadmap Committee's science and exploration objectives focused on whether it would be better to say "Maximize productivity and *assure* safety" with regard to human and robotic explorers, Mr. Diaz distinguishing safety as an important marker. This point is under consideration. In determining whether to eliminate the first objective, as it appears more of a strategy than an objective, Dr. Killeen argued that the need to address fundamental science exploration in order to understand fundamental physical processes (e.g., how stars work) demands retention of this objective. In general, the group noted a good correspondence between Objective 15 and the Foundation Roadmap's objectives.

Asked to what extent the Foundation Committee has sought to fold in other communities, such as the Earth Science community, Dr. Hoeksema responded that some of the communities are addressed, but that he would like this Committee to add depth in that regard. Dr. Giles noted that the SSSC Roadmap Committee has sent emissaries to some of the other Roadmap teams to link with specific expertise and subject areas. Dr. Hoeksema added that within the Foundation Roadmap are identified areas where contributions could be made to the larger vision. Mr. Diaz emphasized the need to map to associated Roadmaps "sooner than later" and to get handoffs accepted or tested. He reminded members that the national directive is to establish a program for sustained exploration, which implies a level of understanding that goes beyond a single event.

To illustrate the Foundation Roadmap's "flowdown" approach, Dr. Hoeksema used the example of Orbit Insertion, Descent, and Landing at Mars to show how the trace starts with what is needed and flows down to the mission: Need → Enabling Capabilities & Measurements → Basic Understanding → Supporting Mission. In detailing the Foundation Roadmap's three objectives, he identified as critically important the need to understand how disturbances propagate from the Sun to the Earth and how the atmosphere responds.

Follow-On Discussion

Dr. Killeen recognized the need to clothe SSSC Strategic Roadmap objectives in the light of new priorities (e.g., going to Mars). Dr. Hoeksema noted that knowledge is needed in any case—to understand in order to better predict—and that this effort supersedes building a predictive system, which was begun with the Living With a Star (LWS) initiative.

State of the Theme: Sun-Solar System Connection

Richard Fisher, NASA Science Mission Directorate

In his presentation, Dr. Fisher urged members to "stop thinking about disciplines and to think about the science that has no name." He called this science "xenology" and the place to study it "The Fifth Great Observatory." Dr. Fisher presented a picture of transformational science that depicted a next generation discovery system and the exploration of a variable heliosphere, focusing on "new horizons." Mr. Diaz suggested that the present Committee connect early with the Earth Sciences Committee, as the two are driven by similar thought processes (i.e., discovery vs. continuance of legacy programs). He suggested consideration of an approach that combined a continuous awareness capability for the environment with methods for using that dynamic system to react to the problems of the day. Because members found Dr. Fisher's thinking "inspiring," verbatim excerpts of his presentation are found below.

"NASA has arrived at a business situation where we are making decisions between commodities and new developments, key tactical decisions that have to be made. Success over the past decade, through strategic missions and judicious use of the Explorer program, has led to The Fifth Great Observatory, which returns data you cannot see with your eye—generally called xenographic data. The continuity and the thoroughness by which this fleet has let us look at the system has whetted people's appetite and given some direction for where we can go in the future.

"The previous legacy missions are about to come to an end as these assets get older and less capable. We're going to start to launch new missions this year—CINDI, TWINS, and a little later STEREO, Solar-B, and AIM—sort of a 'replacement set.' These missions will provide exceptional surveillance of the longitudinal distribution of the magnetic fields and particle flows throughout the heliospheric STEREO mission. I think the state of solar flux is going to be described fairly accurately by the Solar-B mission with Japan, and the SDO is going to allow us to look inside the Sun and at the magnetic evolution. We want to understand that we cannot replace assets one for one; rather, we need to understand what the functions are, what the research uses are, and whether they have any utility in the program for human exploration.

"I was taught out of a book by John Keagan, a professor at Sandhurst, who taught these sorts of ideas to young soldiers. The strategy has three elements: (1) you have to establish a robust goal that you want today, next month, next year; (2) there has to be some kind of available resource, otherwise you're just dreaming; and (3) you have to have the political will to see it through. Now this comes to the point of my excitement today. We have those things in our hands at the present time. We don't have to look to the future. We have vital goals—they have been given to us. We can relate our activities to them and can say why they are important. We do have available resources. We have a 2006 budget with a lot of money in it. We are into commodities and new developments, that is for sure. There is ample support for looking at new experiments and new missions. And finally, there is a vacuum, which I have not seen since the Apollo times, which is from the top. The President said we want to have a sustainable exploration of the universe. So from my standpoint, this looks like a singular moment in time, and I can't think of any other time that has looked like this. All the elements of strategy have been checked off, one by one.

"'What kind of science,' I was asked at the AGU, 'is the agency buying?' A reasonable question, and one that comes from the community. The answer: you want to go for the sweet spot in terms of science activities that are at once vital, compelling, and urgent—all three. This is something that has been taken to heart and acted upon in our discretionary and competing programs.

"When you talk about our field, the structure and process of astrophysics is classically driven by basically the consideration of gravitation and pressure. And out of that there are things to look at—starting with galaxies and planets. About 1880, it became very clear that there were currents in the atmosphere and they were connected to space. The emergence of 19th century technology and the science describing magnetism gave another leg to this, which has been filled out by magnetically driven processes. We recognize now that at the center of our solar system is a magnetic variable that drives the entire system. And the consideration of gravitational magnetically driven forces leads to solar activity in the radiation environment, which comprises a fraction of the things that we are going to address.

"For one, there is a picture of neutral atoms made by IMAGE that you cannot see with your eye, no human has ever seen this, it is a product of the 21st century. There are other things that are phenomological. A picture of neutral gas around the Earth depicts an asymmetry indicating that forces other than pressure and gravity are operating. The primary question facing us and society right now is: is there a single credible mechanism that describes and allows you to quantify the effect of the solar variability of the Sun on Earth's systems? That is a transformational piece of research that will allow prediction—which not only has cultural and intellectual value but has enormous political and economic impact. In the last few years, principally through the efforts of people who have been looking down on the Earth from the upper atmosphere, clear evidence has emerged of how the Earth's chemistry has changed by solar activity. I think at the present time, how deep that goes, how significant it is, is a matter that will require further research.

"In 1998, E.O.Wilson of Harvard University wrote a book called *Consilience*, which literally means a jumping together. What he said was that we are about to free ourselves from those forces which have held us through history. That the reproductive modifications of genomes using quantum mechanics, like electric dynamics and so on, draw from all scientists and may transform how we live and work. There are topical sciences that are ready for synthesis, a synthesis I believe will come around the consideration of transformational sciences, melding electromagnetically driven phenomenon and gravity.

> "A long time ago, just after China opened, I went with a delegation of physicians and watched a lady have a kidney stoned removed with acupuncture. He said, 'Do you want to ask any questions?' I wasn't a physician. The guy next to me, who was a physician said, 'How can you do this with acupuncture?' There was a lengthy expose by the anesthesiologist, and the translator said, 'Physiological principles not well understood.' We're at about that level for the effect of the Sun on the Earth's climate."
>
> *—Richard Fisher, NASA Science Mission Directorate*

"It takes a unique confluence of events and conditions that scientists must enable. Bear in mind that there may be extended transformational activity that will come about naturally. We can come to a place where the science without a name will emerge."

Technology and Mission Study Process and Status

Thomas Moore, NASA/GSFC

Thomas Moore, reporting as the NASA center co-Chair of the Sun-Solar System Connections Foundation Roadmap team, said the Technology/Mission Roadmap Plan will be traceable to NASA strategic goals and Objective 10. He described the study process as flowing from a palette of missions through technical feasibility to a system integration step. Current missions addressing different objectives include Heliostorm, Mars Dynamics, and Mars Aeronomy missions. Dr. Moore noted that a series of technology studies have illustrated interfaces between the SSSC Strategic Roadmap and several Capability Roadmaps, which need to be developed (see chart):

Technology Study	Capability Roadmap Interface
High V propulsion	CRM-1: High energy power & propulsion
	CRM-2: In-space transportation
	CRM-15: Nanotechnology
Compact low-cost spacecraft and access to space	CRM-3: Advanced telescopes & observatories
	CRM-10: Transformational spaceport
Return of large data sets from throughout the solar system	CRM-13: Advanced modeling/simulation/analysis
Visualization, analysis, and modeling of solar system plasma data	CRM-13: Advanced modeling/simulation
Next generation of SSSC instrumentation	CRM-11: Scientific instruments and sensors
	CRM-15: Nanotechnology

Dr. Moore described technology study spirals and decision points, listing typical decision criteria such as experience, most effective approaches, technology developments, transition from research to operations/monitoring, and operational agency agendas. A flow path example showed how decisions are made according to answers found (no, maybe, yes), which then determine next foci and next directions. Operational branch points are integrated within the same schema as they arise.

In sum, Dr. Moore said the "vision for exploration" message has been received and embraced as a welcome challenge. The mandate points to supporting these mission initiatives: particle acceleration, radiation focus; Mars atmospheric dynamics focus; and space weather/climate focus. Technology/Mission studies are well under way and will lead to a responsive new mission set.

Follow-On Discussion

On the consilience model question, Dr. Killeen asked whether the Technology/Mission Study was considering how the missions play together in a constellation of missions (with regard to timing issues, etc.), or whether the thinking was geared more to independent missions. Dr. Moore responded that the thinking was in line with the next Great Observatory platform.

Responding to the question of how this study relates to current studies under way, Dr. Moore said his group currently has missions that do not yet have accompanying science objectives; however, within weeks he expected completion of a flow-down chart that would show applicability of technologies to different missions. Dr. Fisher offered that if members had focused engineering or technology questions, staff would provide appropriate points of contact for answers.

Frameworks for Space Weather Modeling

Stan Solomon, National Center for Atmospheric Research, High Altitude Observatory

Dr. Solomon offered an interesting lunch presentation on the development of modeling frameworks for the Sun-Solar System exploration, presenting heliospheric and geospace models to illustrate code-coupling technology.

The research paper providing the basis of his presentation describes the 3D simulation of a space weather event using the coupled model approach adopted by the Center for Integrated Space Weather Modeling (CISM). The simulation employs corona, solar wind, and magnetosphere MHD models, and an upper atmosphere/ionosphere fluid dynamic model, with interfaces that exchange parameters specifying each component of the connected solar terrestrial system. A hypothetical coronal mass ejection (CME) is launched from the Sun by a process emulating photospheric field changes such as are observed with solar magnetographs. The associated ejected magnetic flux rope propagates into a realistically structured solar wind, producing a leading interplanetary shock, sheath, and magnetic cloud. These reach 1 AU where the solar wind and interplanetary magnetic field parameters are used to drive the magnetosphere–ionosphere–thermosphere coupled model in the same manner as upstream in situ measurements. The simulated magnetosphere responds with a magnetic storm, producing enhanced convection and auroral energy inputs to the upper atmosphere/ionosphere. These results demonstrate the potential for future studies using a modular, systemic numerical modeling approach to space weather research and forecasting.

Dr. Solomon said that someday the interfaces between each of the modules would be cleanly enough defined to allow swapping in of variable data. Next steps for geospace modeling include broader use of OpenDX software, which facilitates the process of animating models and of deriving model outputs and data sets. He suggested putting this software into the hands of grad students and "letting them play," eventually extending availability to the larger community. See www.sciencedirect.com for an overview of this research.

Federal Advisory Committee Act Briefing to the Committee

P. Diane Rausch, National Advisory Committee Management Officer

Ms. Rausch explained the application of the Federal Advisory Committee Act (FACA) to Committee members and their activities, including specific requirements and consequences of non-compliance. Committee members are considered experts to the Government, or Special Government Employees, serving fewer than 130 days a year. Ms. Rausch noted that Congress's intent with FACA was to prevent inappropriate influence on Government decision-making and therefore encourages efforts to engage the public and foster public access. Fact-finding splinter groups are not covered by FACA and may be empowered by the SSSC Strategic Roadmap Committee to investigate specific topics for reporting back to the larger group.

NASA Ethics Briefing to the Committee

Rebecca Gilchrist, Legal Counsel

Strategic Roadmap Committee members are subject to Federal ethics rules because they are "appointed" according to their special expertise and thereby subject to many of the same laws as a Federal employee. Ethics rules are designed to avoid impropriety and competing interests, and to ensure fair, impartial, and credible results.

Ms. Gilchrist cited "particular matters," which are often the triggers for categories of conflict of interest laws: representational conflicts (e.g., with a contract, grant, or agreement), financial conflicts, and post-employment restrictions. The Government is not concerned with prospective contracts on which current members may be PIs, only with contracts currently in place. Members may work behind the scenes on a contract, however. Further, a member may recuse him- or herself from any discussion where there may be a conflict, with the recusal noted in the minutes.

As far as gift rules, no one may give a member a gift *because* of his or her position as a Special Government Employee; exceptions include outside business activities, personal relationships (e.g., Mother's Day), and the $20/$50 rule.

Context-Setting Discussion

Co-Chairs Lead

In this session, Committee members discussed what they had heard thus far and where they might take their study. General comments and action items (highlighted in green) follow.

Citing the notions of innovation and consilience, Victor Pizzo, National Oceanic and Atmospheric Administration (NOAA), asked how NASA would go about pursuing such an approach (i.e., how to effectively plan while also leaving the door open to the possibility of new discovery): "Darwin didn't plan on discovering evolution," he observed. Over the years, a progression to risk aversion has presented a conflict with innovation, with the less risky grants being the ones promoted, for example. The challenge for the Agency is to structure itself to promote discovery while also avoiding an unreasonable level of risk. Other members believed that well-justified arguments were heard for going down both transformational and explorational paths simultaneously.

Warren Wiscombe, NASA Goddard Space Flight Center, noted his enduring conception of the interconnectedness of the Moon, Earth, and Sun, identifying several possible areas of interconnections, including studying the effect of Sun on biology, placing antennae on the Moon and devising a means to explore the gravitation well of Earth.

In observing timescales and schedules, Craig Kletzing, University of Iowa, urged a more reality-based alignment of science goals and timeframes—better pacing—that would put studying the moon ahead of preparing to land on Mars. He said that planning the science in a more integrated manner would better inform plans for the Exploration initiative and would help in managing resources throughout the process. Action: Dr. Kletzing will think through possible phases or waves of activities in this regard.

Jeffrey Forbes, University of Colorado, called for engineering constraints to better frame implementation plans. "What do we need to know about density and wind structure of Mars, for instance, to have a safe descent and landing capability?" he asked. Action: Dr. Hoeksema will develop Roadmap-to-Roadmap questions relative to technology, time domain, and requirements for the Mars atmosphere. Mr. Diaz said these three elements should be discerned—sooner than later—as part of Roadmap-to-Roadmap questioning.

Donald Hassler, Southwest Research Institute, said the degree of overlap calls for a workshop wherein the different Roadmap Committees would present to one another, enabling an appreciation of what each has to offer the process as a whole. Even though joint sessions are already planned with the Earth and Lunar Committees, the workshop idea is a different concept that would allow members to interact and share ideas over an extended period, beyond listening to a presentation from one Committee representative. Action: Barbara Giles offered to work toward that end, noting that the Mars meeting is scheduled for March 29.

Other members supported an approach that would aim to tie these communities together, Mark Weyland, NASA Johnson Space Center, adding that the time is ripe to capitalize on the enthusiasm of progress being made with vehicle shielding design. Contractors are already examining materials and different vehicle designs.

Scott Denning, Colorado State University, suggested looking beyond space science and linking to exploration. Referencing NASA's reorganized science enterprise, he suggested making linkages across different divisions. He said the SSSC Roadmap Committee could link with at least six other Roadmaps, capitalizing on investments already made. He liked the call to "follow the energy" and the Sun-to-Mud theory, which implies the need for Earth Sciences to contribute. Action: William Gibson, an engineer from Southwest Research Institute, will examine underlying technical feasibility issues—that is, he will look at how mission studies can incorporate exciting new science *and* remain relevant to the Exploration initiative. In many cases, he said, it is not difficult to adjust the ranges of instruments, for example, to make a product useful to the Exploration initiative.

Todd Hoeksema pointed out that how the two teams work together—the Foundation Roadmap and the Strategic Roadmap—is critical. The Foundation group and this group will need to ensure that as they each identify particular messages, these are promptly shared, integration issues being key.

Michelle Thomsen, Los Alamos National Laboratory, liked the synergy shown between the transformational and enabling types of science in the work of the Foundation group. She believed that both of these types should be acknowledged in the Strategic Plan as being crucial. "The foundational work we're doing now will allow the new visions of tomorrow to form," she observed, "whatever they will be." She spoke of the nature of science as proceeding in a "filling-in" and consolidating manner, permitting the application of new knowledge for more practical purposes. The challenge is to strategize a program that is agile and that enables this shoring up and consolidating function while also maintaining the situational awareness that allows for identification of new ideas and new discoveries.

In summarizing the themes of this discussion, Dr. Killeen cited "branching paths" created as learning occurs into the future: predicative capabilities, safety issues, situational awareness of geospace—perhaps threads exist there that can be drawn together. A system-to-systems approach can be both transformational *and* exploratory, all of which supports a human diaspora in space and generates much excitement for Moon, Mars, and planetary exploration.

In closing, Mr. Diaz expressed his hope that NASA's reorganization would spur people to think differently. He said this is likely to be a "liberating opportunity," but will also require courage to stay committed to maintaining the foundation while looking to the future and calling for new demands on the science. "We are hopeful that the tradition that Earth Science has developed will find its way into Space Science," he said, adding that much energy will be needed to keep pushing in that direction, to keep believing there is something different out there, without abandoning the foundation in the process.

Identification of Sun-Earth Integrating Science Questions: Connections to Earth Science

Scott Denning and Warren Wiscombe Lead

Dr. Denning noted that in addition to supporting the President's vision for space exploration, the Earth Division must support two other top-down Presidential directives: the Climate Change Program, to which NASA contributes about $1 billion a year; and partnering in the International Global Earth Observing Systems (GEOS). Earth Science at NASA supports the President's vision for space exploration *and* these other two directives. It also synergizes well with the Solar System and Universe Divisions. Dr. Denning said that one obvious area of interaction is characterizing the environment of interplanetary space and predicting it using models, then comparing predictions to a next suite of observations to determine optimization. This type of research is essential to the Earth-Science part of NASA. Indeed, NASA has shown leadership in bringing space-based forecasts into the weather prediction arena. A maturation in climate change in space will also require reliable climatory predictions, and from that requirement will flow many science and engineering activities. It is when observational data is fed into predictive models and they fail that learning occurs. The Sun-Solar System community will gain by using real observational data and testing models.

Dr. Denning noted that the solar system drives every molecule of biochemistry on the planet and found excitement in the notion of combining all the different codes into one science directory. He said that while a model takes a static snapshot, a telescope—sufficiently large to capture enough photons—could monitor the space phenomenon as well as observe what happens on Earth in a dynamic way. This is transformative science applied to studying the interactions between Earth Science and Space Physics as part of an observational system.

Dr. Wiscombe urged that fundamental measurements associated with increased aerosol loading on the troposphere and changes of heat flux in the atmosphere—solar radiation that propagates to other things—not be lost. He cited a Dave Thompson study, which found that changes in the chemistry of the Stratosphere propagating down to the Troposphere may account for as much as half of the observed warming at high latitudes. Dr. Killeen offered that looking at that calibration would be a transformational science approach and a possible L1 candidate. Donald Hassler added that NASA's assets are aging and that part of the group's strategic mission should include investigating these types of instruments.

Tim Van Sant, SSSC Roadmap System Engineer, said that a solar sail mission able to double the warning time with regard to solar particles would have modest remote sensing ability at best, as the sensor would be upstream approximately 2 million miles from Earth. He said that having a mission at L1 would optimize this capability. Dr. Hoeksema said the solar mission to really follow on would be SDO, which has no Earth-observing content or coronagraph, but does spectral radiance measurements. Action: Tim Van Sant, Warren Wiscombe, and Todd Hoeksema will collaborate and report back on irradiance. Specifically, the SSSC Roadmap needs to consider how to ask the right questions in this regard in order to prepare the way for biology in space (i.e., what the environment does to plants and animals). Dr. Wiscombe said he would keep stressing the need to include Moon and Sun observations into these discussions.

Dr. Wiscombe also urged more consideration for what humans could do in space to optimize efficiency of resources. "A human geologist could do in one day what it took the Mars probe 90 days to do," he observed.

Dr. Forbes asked several questions perched on the threshold of consilience and transformational science: How do we separate anthropogenic change in climate from solar change? To what extent does electrical coupling affect climate? To what extent do energetic particles influence ozone chemistry and affect climate? He called NASA's reorganization "timely" in that it allows the Committee to begin to address these interdisciplinary problems, and said it was good that Earth Science and Space Science must now work together, particularly given their similar basic physical processes. Action: Warren Wiscombe will participate in the Sun-Earth Integrating Science Subcommittee, in place of Scott Denning.

Human Flight Space Weather

Mark Weyland, Manager, Space Radiation Analysis Group, NASA – Johnson Space Center

Mr. Weyland said a Draft Request for Proposals (RFP) for the first three spirals has been completed, and NASA is already looking at shielding for the first set of vehicles. Therefore, SSSC Roadmap input needs to be made quickly. Action: Michael Wargo, NASA Exploration Systems Mission Directorate, will arrange a briefing to be distributed to the SSSC Strategic Roadmap Committee, to include the Space Radiation Analysis Group timeline and spirals discussion.

Mr. Weyland continued by noting that the optimal time to make adjustments to keep exposure to solar particles as low as possible is during the design phase. He added that having a capability to react to occurrences as they come into view (in real time) would be well received. Currently, no predictions are done. Action: Mr. Weyland will check on the availability of the deep space environment draft for the SSSC Strategic Roadmap Committee's discussions. He will also look at deadline dates (with Michael Wargo) and will get back to the Committee with this information. (He did note that radiation shielding requirements have *not* been released for the Lunar Lander.)

Commenting on the difference between quantitative limits and the alora principle, Mr. Weyland said "ALORA" refers to keeping exposure to radiation as low as reasonably achievable. Having the ability to lower that limit and thereby lighten the load that astronauts carry for shielding purposes would be helpful and would make predictive information highly valued. He noted that biological effects have a 300–600 percent uncertainty rate and is where investments are needed in order to buy down risk and buy down the associated impact on resources.

Dr. Killeen asked for the 'gotchas'—those items that must be known or had in order to proceed a certain direction. As far as what he would like to have, Mr. Weyland said that being able to predict the occurrence of a solar particle event would be the "holy grail." He also listed the following as desirable:

- Solar cycle models beyond solar maximum and minimum
- Models/measurements characterizing shock propagation and solar particle flux gradients at various points in the solar system
- Continued space-based observations of CMEs and SPEs.
- Galactic Cosmic Ray (GCR) modulation (including Be-10 measurements at 11, 14.5, 22, and 24-year cycles and beyond)
- GCR models of modulation
- Measurements and models of relevant energy spectra and composition at mission locations
- Radial gradient
- Space- and ground-based measurements
- Data access and archives coordination

Asked to identify the "top 3" areas in which he would like to see advances made, Mr. Weyland answered more prediction with solar particles and models of modulation (knowing where you are going to be). Dr. Killeen summarized the three "weigh stations" emerging from Mr. Weyland's presentation for this group's purposes as: clarifying the milestones, informing the designs, and providing predictive capability. It was agreed that current data sets should be examined for any utility they might immediately provide to the Space Radiation Analysis Group.

Operational Space Weather

Victor Pizzo, NOAA

Dr. Pizzo said that each of these emissions from the Sun has effects on Earth; therefore, NOAA tries to keep track of all of them to some extent:

- X-Rays, EUV, Radio Waves (radio communications, navigation signals)
- Energetic Particles (astronauts, spacecraft, airlines, radio communications)
- Solar Wind Structures (radio communications, navigations, electric power grids, pipelines, satellite drag, spacecraft charging)

The role of NOAA's Space Environment Center (NOAA/SEC) is to serve as the Nation's official source of space weather alerts and warnings and to synthesize space environment data and information for dissemination to a broad range of users. NOAA/SEC also conducts directed research to develop new understanding and to bring models, data, and predictive schemes into operations. NOAA has back systems and QA and verification for the data that go out, and is one way in which operations and services are distinguished from exploratory research.

Dr. Pizzo called for cooperation among all agencies with observational resources for making space weather forecasts (e.g., NOAA, NASA/ESA, DoD) to achieve synergy with the available data and to further understanding about the prediction process in the geospace environment, which reacts differently according to different solar inputs. There are also much ground-based data that can be used as well from DoD, NOAA, USGS, and NSF-funded observatories.

Dr. Pizzo said he would like to have routine white-light monitoring (i.e., coronagraph) from multiple view angles over a wider range of heliocentric distances. He added that because L1 cannot go too far upstream, another STEREO-like observatory with in situ monitoring ability would be ideal. The ability to measure the magnetic fields in the corona would also be highly prized. Dispersed in situ monitors would help develop a greater understanding of heliospheric propagation, and mutli-point in situ monitoring would help to build up a record and validate models. Finally, Dr.

Pizzo said an improved and more global ionospheric observing system is needed to achieve resolution of temporal/spatial confusion.

Asked whether NOAA is planning on putting something in place to achieve "another view off," such as what STEREO could provide, Dr. Pizzo responded no, yet this is what is needed. Whether NOAA will fund it remains unknown. He added that the bigger question is: who will develop predictive capability for the future, and how will it be developed? This question must be worked out, he stressed, noting that gaps would become apparent quite soon. Dr. Killeen asked the Committee to what extent it should assume that other agencies are "picking things up." He said if exploration is a top priority, and the NOAA "wish list" items are needed to ensure health and safety, then that is how it must be intentionally positioned. Dr. Thomsen reiterated that NASA has shied away from operational capability; however, she added, given the necessity of monitoring for exploratory research, monitoring could be viewed as a "facility" that does not then hinge on whether NOAA is paying for it.

Dr. Giles pointed out that the objective clearly draws the line between NASA and NOAA and that NASA's job is to demonstrate the technologies to improve future operational systems; therefore the monitoring need may be put into the Roadmap in any way desired.

Discussion and Overnight Assignments

Co-Chairs Lead

The following subgroups were named, whose members would report out the following day:

1. **Overall Rubric, Framing**—Michelle Thomsen, Richard Fisher: What is this thing that has no name, whose makeup includes agility, predictive knowledge, awareness of geospace environment?
2. **Timeline**—Craig Kletzing: Phased approach strategy.
3. **Requirements Issues**—Todd Hoeksema: Radiation environment, health effects, prototype capabilities, etc.
4. **Earth-Sun-Science Connections**—Scott Denning: Could be where L1 would really come in.
5. **Disruptive Technology**.

Dr. Giles acknowledged the need to form a list of interfaces with other Roadmaps, an effort begun but not completed and one that lends itself to a systematic approach requiring a prioritization effort within the APIO framework.

The meeting ended at 5:15 pm.

Day 2

The meeting was convened at 8:30 am. Those in attendance on Day 2 are listed below:

Strategic Roadmap Committee Members

Al Diaz, NASA Science Mission Directorate, co-chair
Tim Killeen, National Center for Atmospheric Research, co-chair
Scott Denning, Colorado State University
Jeffrey Forbes, University of Colorado
William C. Gibson, Southwest Research Institute
Donald Hassler, Southwest Research Institute
Todd Hoeksema, Stanford University
Craig Kletzing, University of Iowa
Victor Pizzo, National Oceanic and Atmospheric Administration
James Russell, Hampton University
James Slavin, NASA GSFC
Michelle Thomsen, Los Alamos National Laboratory
Warren Wiscombe, NASA GSFC
Barbara Giles, Mission Directorate Coordinator, DFO
Azita Valina, APIO Coordinator

Ex Officio and Liaison Members

Richard Fisher, NASA Science Mission Directorate
Michael Wargo, NASA Exploration Mission Directorate
Mark Wyland, NASA Johnson Space Center;
Rosamond Kinzler, American Museum of Natural History, Liaison with Education Strategic Roadmap Committee

Others

Thomas Moore, NASA GSFC
Tim Van Sant, NASA GSFC
Jennifer Elcano, Infonetic
Craig J. Pollock, NASA HQ
Robert Hoffman, NASA GSFC
Michael Calabrese, NASA GSFC
Ray Williamson, George Washington University
Robert Forbes, NASA HQ
L. Frehlich, NASA HQ
Charles P. Holmes, NASA HQ
O.C. St. Cyr, NASA GSFC
Steve Suess, NASA MSFC
Rachel Weintraub, NASA GSFC
Jim Spann, NASA MSFC
Phil Richards, NASA HQ
Eric Christian, NASA HQ
Giulio Varsi, NASA HQ

Subgroup Report-Out

Designated Subgroup Representatives

Members who were designated as subgroup leaders reported their preliminary assessments for the topic areas identified.

Overall Rubric—Framing

Michelle Thomsen

Suggested Overview Bullets:

Dr. Thomsen suggested a rubric for the SSSC Strategic Roadmap document—specifically, what an introductory paragraph might look like. She suggested an overview that would include the following points:

- Our program will help assure the safety of the new generation of human and robotic explorers.
- At the same time, we will pursue a deeper understanding of the fundamental physical processes that underlie the awesome phenomena of space.
- We will develop a predictive capability to address hazards to space travelers and to important technological assets closer to home, and learn how fundamental space processes may affect the habitability of other distant environments beyond our own solar system.

Member Feedback on Bullets:

- Introduction should say **"maximize productivity"** to be more dogmatic, and **"is critical to the assurance of the safety…"** in that same vein.
- The second bullet does not incorporate Earth climate issues and is missing the basic science piece. Perhaps an addition such as **"…space, and its effects on the Earth's climate,"** or something similar could address this.
- Also in the second bullet, may want to change **"pursue a deeper understanding"** to language that is more transformational. To this comment, James Slavin responded that fundamental processes must still be emphasized as a tactic to achieve the strategic goals related to Earth, Moon, and Mars. Emphasis on "understanding fundamental processes" is needed to derive a predictive physics-driven model that meets the operational need. "We can't get there by brute force," he noted, "because it is too expensive just to launch things into space."
- Scott Denning suggested breaking the third bullet just before **"learn"** into a fourth bullet.
- Dr. Killeen suggested that the phrase **"understanding the home base for future human exploration"** and that **"safety through physics"** or something similar be added to bullet 1. In general, members wanted the language to be more emphatic and stress more of the transformational flavor of Dr. Fisher's presentation. Dr. Slavin called for including both transformational (ignition point) language, together with explicit language that is elucidatory of the concepts being contributed to this enterprise.

Dr. Wiscombe suggested that the group consider the European approach where the community as a whole would create a *single* model of the Sun and begin to conduct observing-system simulation experiments to test where to place assets, using computerized models to help maximize return. This is a physics-driven approach and may be close to being a first step, he said. Another member suggested that the group advise NASA with regard to institutional frameworks that need to be developed; perhaps a NASA Center could begin to formulate a Heliospheric Center Community Model.

Dr. Killeen said that the SSSC Strategic Roadmap Committee should state more declaratively that the time is right to engage in such efforts as model coupling, data simulation, observing-system strategies, special and temporal scales, and to issue more of a grand challenge. Several relatively recent changes make this the right time to cross a new threshold: advances in IT, the march of technology, sensor development, remote sensing, etc. Dr. Killeen suggested possibly weaving this state of readiness into the Roadmap document to demonstrate that the community is positioned for the next big step. Dr. Giles suggested breaking each bullet into parts, with a different type of modeling recommended for each.

Dr. Wiscombe observed, "For a bunch of scientists to say we need to do more science is not too exciting." He advocated creating a "big tent" that becomes a focus for the entire community, wherein everyone begins talking the same language and working together to improve the same model—an approach that has worked well in Earth Science. He said it is too difficult to discuss predictive capability with multiple models in circulation, to which Dr. Hoeksema responded that too many exist to pick just one at this point without a systematic comparison. Dr. Killeen called for developing and using the software engineering that students and others are using within the "same universe," going beyond a little modeling database.

Dr. Hassler pointed out that the underlying research effort is what engages this community—before elements are fixed and standardized in the operational phase. Dr. Killeen noted that tech transfer from research to operations is facilitated by being more systematic and structured in the environment one is working in, which leads to model development.

Dr. Killeen suggested redrafting the three bullets to reflect the following three themes:

- Characterizing our home in space
- Safeguarding our outbound journey
- Building the knowledge system for heliospheric modeling/learning

Sample Introductory Text:
Dr. Thomsen provided the following sample introductory paragraph, based on the overview bullets:

> The exotic environment of space beyond Earth's protective atmospheric cocoon is highly variable and far from benign. Strongly influenced by the variability of the Sun, a host of interconnected physical processes occur that affect the habitability of other space locales and the health and safety of travelers to those destinations. Building on NASA's rich history of unmanned exploration of the Earth's neighborhood and distant planetary systems, we will develop the quantitative knowledge needed to help assure the safety of the new generation of human and robotic explorers. With focused research addressing specific space environmental hazards, we will help guide the design and operations of safe and productive Exploration missions. At the same time, we will pursue a deeper understanding of the fundamental physical processes that underlie the awesome phenomena of space. This scientific exploration will target the highly coupled system that stretches from the Sun's interior to planetary neighborhoods and the vast expanses of interplanetary space. We are now transforming human understanding of this fascinating global system of systems, so closely connected that the same explosive event on the Sun can produce power outages on the Earth, degradation of solar panels on interplanetary spacecraft, fatal damage to instrumentation in Mars orbit, and auroral displays at Saturn, effects that span the entire solar system. By expanding and deepening that understanding, we will not only develop a predictive capability to address hazards to space travelers and to important technological assets closer to home, but we will learn how the fundamental space processes may interplay to affect the habitability of other distant environments, beyond our own solar system.

Member Feedback on Sample Text:

- Add the effect on habitability of Earth at the end.
- Suggest restating as **“predictive capability that will allow travelers and designers of future systems to successfully deal with the hazards of space.”**
- Missing NASA objective of informing the design.
- Needs more of the transformational aspect, specifically: “Which part are we going to make progress in transforming over the next 20 years?” Perhaps Dr. Fisher could assist in the rewriting.

A Phased Approach

Craig Kletzing

In considering the pace of activities, Dr. Kletzing said his approach was to try and couple the timing of activities with where the SSSC Roadmap Committee could make the most appropriate inputs. Three points, or phases, emerged:

1. CEV (expected to be ready for lower orbit around 2010)
2. Moon landing and operations (around 2015 – 2020)
3. Mars (around 2030 – 2035)

With regard to #1, the RFA has already been released for the exploration vehicle; however the lander is more distant (2030 – 2035) and will require some specification of atmosphere and vehicle design by around 2015, a date Dr. Kletzing’s group set for having aeronomy inputs ready. He said that waiting even five years beyond this date will put the Committee “outside the window” for being able to actually influence any design.

With regard to #2, the Moon is still a near-Earth environment, which suggests for the relatively short-term future looking at issues of understanding the Earth environment to the extent possible and beginning to develop some reasonable observing capability to assist with going to the Moon. These relatively short trips better align with how predictive capability will develop. Dr. Kletzing observed that predicting for the Moon is essentially predicting for the Earth, enabling a “bang for your buck” argument. In the relative near term, it will be important to get assets in place to really understand the near-Earth environment.

With regard to #3, the notion of assets at large—for the actual voyage to Mars—is a more distant problem, although Dr. Kletzing added that now is the time to build the needed groundwork and is where fundamental physics starts coming in. “Now is the time to do that work because it should be developed and in place to allow future capability.” While some attention must also be paid to the type of observing assets that will be needed to assist the Mars mission, these, too, are relatively far off. He concluded by observing that while there seems to be some urgency with conducting aeronomy at Mars, the nearer system should be taken care of first.

Member Feedback on Phases:

- Dr. Slavin submitted that because of solar terrestrial probes and LWS, both of which pre-date the Exploration initiative, the first spiral is already under way. He said completing this spiral would accomplish two things: (1) provide what is needed to conduct physics-based modeling predictions and (2) support the Exploration program, at least through to initial Moon landings in the 2010 – 2015 timeframe. It will also facilitate arrival at a natural assessment and decision point with regard to the second spiral. Dr. Slavin still urged a preliminary look at providing operational support for when the astronauts are actually transiting to Mars and eventually working and exploring there. He added that if the Exploration program is to use aero-braking, much less aero-capture, some type of new upper atmosphere aeronomy Mars mission needs to be rolled up in the 2007 or 2008 (at the latest) budget. "The rest of it is pretty much in place," he continued, "we just need to hold to our schedule and complete this first spiral."

- Another member noted that linkages with other communities are needed to discover their real needs based on real limits, this "coupling" being an important part of demonstrating responsiveness. Dr. Hassler observed that limits are generally based on an operations and engineering mentality, and that given the lack of limits currently for deep space, one must think beyond "tripping their limits" when asking experts for their input.
- Dr. Thomsen restated the balance proposed by Dr. Kletzing as (1) needing to focus on requirements for design (e.g., mission design, vehicle design, etc.), this being the most immediate need, which, to a large extent, means exploiting the body of understanding and information that has already been accumulated in developing the spiral and (2) developing a new knowledge base to support operations, a longer term goal that will require new understanding and new predictive capability emanating from more Foundation studies. The latter will continue to be worked on, with a product developed later, when the operational predictive capability is required. Dr. Thomsen ended with a question: "We have a lot of work to do to put what we know into a framework that is useful for design, but what are the new things we have to do to support the design phase?

Michael Wargo, NASA Exploration Systems Mission Directorate, said that this Committee could make meaningful contributions to improving predictability models and mission productivity by doing more to assure safety. He added a caution about speaking in absolutes, that while there are contributions to design that will help ensure safety (e.g., CEV, radiation limits, shielding), the model itself will not make people safe; rather, safety is more likely to be a factor of having predictive capability for transient events to help astronauts avoid exposure. Action: Dr. Kletzing will provide a draft for Dr. Wargo to share with colleagues for their input and reassurance. The draft will be prepared for the next meeting.

Requirements Issues

Todd Hoeksema led a group to define questions that should be asked of other Roadmap teams.

Questions for Other Roadmaps:

- To what accuracy must density and winds in Mars atmosphere be known in order to ensure safe aerocapture, entry, descent, and landing of a manned spacecraft?
- To what extent does strategy for design and development of aerocapture, entry, descent, and landing of a manned spacecraft depend on density and wind variability in Mars' atmosphere?
- What is the safe radiation dose astronauts can be exposed to (total dose, spectra)? Limits for evolution of life on other planets?
- What radiation environment characterization information is needed for spacecraft design (CRV and other robotic spacecraft)?

Member Feedback on Questions:

- Change "**spacecraft design"** to **"mission design."** That is recommendation.
- The last question is more relevant than the third (i.e., "what do you need to know") and can be addressed by radiation experts.
- Need to expand characterization and prediction aspects of these questions to better relate to the SSSC Strategic Roadmap Committee's focus of enhancing predictive capabilities.
- Need to know more about requirements and knowledge gaps, particularly as they relate to landings.
- Need to add something about "direction" in second question.
- Include time scale in questions.

Azita Valinia, APIO Coordinator, said she would refine these questions to elicit the answers needed. Asked how well he knows what he needs to know, Mr. Weyland, NASA Johnson Space Center, said the biologists are the ones focusing on knowing the modulation of the environment—an important and helpful piece, particularly if it can be known in advance where the GCR cycle is going to be.

Dr. Giles urged the bringing forward of new data sets into this process to ensure that characterizations are based on the latest available information.

Earth-Sun-Science Connections

Scott Denning

Earth-Sun Science Questions:

- How can integrated Earth-Sun observing systems be optimally combined with physical understanding to develop quantitative characterization of the fluxes of energy and particles from the Sun to the Earth's surface and back to interplanetary space?
- How do variations in the flux of high-energy particles affect stratospheric chemistry and dynamics, tropospheric circulation, and the Earth's climate (for both L1/L2 daytime and nighttime missions)?
- Do GCRs affect clouds and climate on Earth?
- How does the Earth's changing climate affect the dynamics and physics of the (middle?) outer atmosphere?
- Can observations from the lunar surface and subsurface help us learn about the behavior of the Sun in the past few centuries (boreholes, solar "debris")?

Member Feedback on Questions:

- L1/L2 mission would be salutary for Earth scientists as they do not typically think beyond low Earth orbit. To be able to see the dark and light sides of the Earth at once via a global change, macroscopically would be new; currently, geostations do not see the whole globe. The L1 point is also good for looking at normal solar photons, but L2 can get simultaneous limb sounding that "lights up" the Earth and reveals minute-by-minute chemical reactions.

- It is unclear whether the SSSC Foundation Roadmap has the geospace, Earth-cloud expertise to do the above; other Roadmaps may be better positioned. A "big mission" might be able to combine Earth-Sun for the first time.

Action: Dr. Denning will work with Dr. Wiscombe and with the SSSC Foundation Roadmap Committee to flesh out L1 and L2.

Presentation by Walter Schimmerling

The Committee asked Dr. Schimmerling to help it understand time frames, tolerance, predictability, and other factors illuminating the goal of assuring safety and maximizing productivity. Asked to describe the most damaging photons to plants, Dr. Schimmerling said the two sources of radiation of concern are cosmic rays and protons, each posing different problems relative to predicting risk to astronauts in space. High-energy protons worry him the most in terms of biology because they can go through the spacecraft designed to mainly keep out the low-energy protons.

Data from atomic bomb explosions have provided most of the information on health effects; however, that information described gamma ray dose delivered over a short period of time to a population under stress, which differs greatly from the target population here—a healthy population facing long-term exposure. Converting these data for applicability to the target population requires examining the dose-rate effect, which presents additional problems stemming from differences between gamma rays and charged particles, the latter having a large amount of energy in a single cell.

Even though much is known about the biological effects of high-energy charged particles, great areas of uncertainty exist relative to high dose versus low dose and gamma versus cosmic rays. Assessment capability allows for predicting risk to travelers to Mars with an uncertainty factor of five (five times greater or less), the main sources of uncertainty being the biology involved in going from a high dose of gamma rays to a low or medium dose of charged particles and going from gamma rays to GCRs.

Dr. Schimmerling said much stands to be gained from biology research and that a fairly extensive radiation program is in place with two components: radiation shielding and radiation health (trying to solve the biology problem). Output is expected to suggest several ways to improve risk (e.g., with shielding materials). Part of the shielding project is to come up with new materials or configurations that will have the same advantage of water or polyethylene, but that can be used to replace steel and aluminum fixtures. Most importantly, biology results will suggest ways to reduce risk, work more safely, and deal with radiation effects, leading to greater gains than with other approaches. That said, the solar particle event problem is a different problem because of the inability of predicting when an event will happen, where the particles will go, and what the maximum duration and intensity will be. It is a problem of false positives (about 50 percent) as well as negative predictions.

In the short run, **"nowcasting"** capability is the most important area to focus on—to use 3D modeling to see distributions, as well as to discern how and where shock waves will occur and how long they will last. These important items are what the solar particle community should address. "If you can predict or tell us one hour ahead, that is the most important thing you can do," Dr. Schimmerling concluded.

Asked to identify the top safety concerns for life, plants, humans, and infrastructure-spacecraft, Dr. Schimmerling responded that most silicone devices will function after being hit by 10^{10} and 10^{9} particles, while most people will not. So if people survive, their equipment will likely still work. On the timescale of a human expedition, there likely will not be enough solar radiation to have an effect.

Asked whether there is an extensive program within the Human Exploration Program examining the vulnerability of critical life support systems, Dr. Schimmerling said the intention is to use ground-based space radiation labs to simulate radiation and discern its effects on electronics/devices, an approach that generates great cost advantages.

SSSC Roadmap Science Objective 1

Craig Kletzing, University of Iowa

> Objective 1: Understand the fundamental physical processes of the space environment—from the Sun to Earth, to other planets, and beyond to the interstellar medium.

Dr. Kletzing said the goal of Objective 1 is to come up with predictive capability. He said the field is at an interesting transition point currently, and that while physics has always underlied it, the trend is fast moving from relatively morphological descriptions to looking at the detailed processes in order to really understand how different pieces of the system work. Most of the key places and processes are known in terms of what needs to be investigated, and now better measurement sets are needed to describe technological capability. The availability of multipoint measurements in particular is helping to bring about breakthroughs. Applications are resulting from basic research currently being conducted, laying the groundwork for the future. Dr. Kletzing then described the various research focus areas (RFAs) under this key Objective.

RFA 1.1

The first focus area is aimed at understanding magnetic reconnection to reveal the cause of solar flares, coronal mass ejections, and geospace storms. Magnetic reconnection is a process that, although known about for a long time, lacked a detailed understanding of how to predict system workings. Now the understanding has evolved to where the types of measurements needed to "crack this problem wide open" are known. Therefore, an argument could be made that understanding reconnection allows for better predictions of how the Sun works and provides a rationale for gathering that predictive information local to the Earth. It is far less expensive to fly probes through the corona, a feasible approach that requires only its execution. In other words, continued Dr. Kletzing, this is really a focus area well poised to engage in transformational science and is an area identified as having implications for building better predictive models.

RFA 1.2

The second research focus area is aimed at understanding the plasma processes that accelerate and transport particles. Dr. Kletzing noted the existence of a "pretty good catalog" of the various places where particles are being accelerated, where one can see the shock going outward. Still, to be able to put any real physics into the acceleration process is a missing piece of the puzzle. Nice pictures are available, but in many ways the physics is still at a somewhat "cartoonish stage" because acceleration processes are inherently tough to fully comprehend. Again, an understanding of the basic processes is needed to achieve any kind of reliable predictions.

RFA 1.3
This RFA examines planetary atmospheres to delineate how planetary upper atmospheres are affected by energy inputs. It calls for getting probes into the upper atmosphere in order to understand the underlying physics, a difficult problem that can really only be addressed with sounding rockets, which is where much of the research has occurred. Remote sensing has become increasingly important, but still the understanding is relatively primitive. "Yet here we're going to go off to Mars," observed Dr. Kletzing, "and we're going to try to run things through here, and as we heard earlier, issues of gravity waves interacting with the vehicle coming in could cause it to bounce around when entering at high velocities from interplanetary space—and you'd rather like to be precise about this stuff." Energy inputs such as solar irradiance and particle precipitation can all impact the chemistry and structure of the upper atmosphere, and not enough is known to be able to explore different places. This is a key area of needed focus so that models able to provide end-to-end coverage—from Sun to Mud—can be derived.

RFA 1.4
The fourth RFA goes to the issue of how solar and planetary magnetic dynamos are created and how they vary. Dr. Kletzing called this one of *the* classic problems in physics overall as a discipline, that is, how dynamos work. It is of particular relevance because it is what drives the variability of magnetic fields on the Sun and the Earth. This is a fundamental problem that, as it is better understood, will enable better predictive capability in terms of how these variations come about. The driver is to work toward predictive capability and away from black box capability, which simply states results seen previously (i.e., when x happens, y happens). Understanding of the underlying reasons *why* something happens needs to be better developed and actually propagated through the system.

Follow-On Discussion

Michelle Thomsen noted that the thread of this being the "system of systems" was missing, and that the reconnection discussion naturally lends itself to bringing in drivers of reconnection from the outside, or those elements in the ionosphere that may affect the processes involved. Connecting these occurrences with some type of thread goes back to a strong theme associated with this field. Benefit could also be gained by expanding this perspective to the other planets—to make something of how the processes actually apply elsewhere in the solar system and in the universe. Lastly, she noted no acknowledgment in the acceleration discussion of the fact that magnetospheres are very powerful particle accelerators. Action: Dr. Pizzo will work with Dr. Kletzing to clarify the language addressing Objective 1, particularly to ensure that it does not read as if reconnection causes magnetism, for reconnection really occurs more at the end of a large-scale slow buildup and stems from converging flux, slow transport of flux on the surface, and gradual twisting—so it is really more an incidental than a causative process. Explosive release occurs *because* of the reconnection, and that is the site where the magnetic energy is converted—at least in terms of many of the forms of particle energy seen.

Dr. Slavin expressed concern about accurately and prominently portraying the role of reconnection and particle acceleration in coronal dynamics, which gives rise to so much space weather phenomena, so as not to divert focus from or jeopardize funding for addressing the physical underpinnings that cause these phenomena.

Dr. Killeen raised the "Devil's advocate" question of "How is this all playing together, how do we knit it all together?" Dr. Slavin responded that the community involved with the International

Solar-Terrestrial Physics Project (ISTP) is where the connection takes place, the definitive demonstration of the role of reconnection. MMS, the next arc, will show how it works.

Dr. Kletzing suggested starting out by saying that knitting together a detailed understanding of these pieces into a bigger whole enables going beyond the limitations of the black box—that the knitting together is what makes it interesting, not the fact of something being known unto itself.

SSSC Roadmap Science Objective 2

Don Hassler, Southwest Research Institute

> Objective 2: Maximize the productivity and safety of human and robotic explorers by developing the capability to predict the extreme and dynamic conditions in space.

The emphasis of this objective is the deep space environment out of the Earth (geosphere) environment, which is different than Objective 3, which focuses on the Earth system and terrestrial applications specific to life, society, and the habitability of plants. Although the Sun is the driver of the two space environments, the applications and challenges are different.

CMEs and solar particle events (SPEs) are disruptive, high-energy events with nearly isotropic radiation environments that demand predictive capability for astronauts in space. In converting science to operations, forecasting SPEs in order to minimize risk in exploration activities is the biggest single challenge (e.g., to mitigate the dangers of being caught away from a shelter on the Lunar or Martian surface). Predicting SPEs is a multidisciplinary challenge requiring a long-term strategy that is developed and modified over the evolution.

Following the presentation, Dr. Thomsen questioned the singular focus on solar energetic particles, asking whether other potential contributions to the Exploration initiative should be included and made more visible. Dr. Hassler responded that other aspects would be included and that solar particles represent just one well-developed example. Dr. Thomsen suggested that, to be more inclusive, other aspects of potential hazards linked to space-environmental conditions should be included up front to break up the solar-only focus of RFAs 2 and 3.

SSSC Roadmap Science Objective 3

Jeffrey Forbes, University of Colorado

> Objective 3: Understand how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields.

This objective addresses the impact of the space environment on humankind, principally on Earth, but also throughout the solar system, as part of our exploratory endeavors. The pertinent questions include:

- How do solar disturbances evolve and affect planetary environments?
- How do the changing Sun and space environment influence Earth's climate?
- How do magnetic fields influence planetary habitability?
- What can we learn through the study of other planetary environments and their interactions with solar-heliospheric disturbances?

Member comments include a request to modify the **"what can we learn language"** in bullet 4 to something more dynamic. Another comment cited too much redundancy and singular emphasis on solar energy and propagation. Dr. Hoeksema countered that the Foundation Roadmap's top-down approach has given rise to questions that need to be asked, producing inevitable overlap with missions feeding back up in multiple ways, which actually makes them stronger; the language just needs to be presented better, with perhaps more cross-references used instead of recapitulating the same analyses.

Dr. Hoeksema acknowledged the need to better justify each objective, so that the motivation for doing it is more strongly presented and the flowdown/crossover works more effectively—that is what he will take back to the Foundation Committee. This may result in a merging of some of the RFAs. Dr. Killeen reiterated that the SSSC Strategic Roadmap Committee will likely end up abstracting and repackaging materials from the Foundation Roadmap for its own report. Prioritization makes the timeline critical, which speaks to the phasing issue. He suggested starting from the most important, compelling needs, then building to the synergistic knowledge system discussed yesterday. Many of these questions, being open-ended, are not the kind of statements that will lead to a sustained program, he posited, urging that questions about how to inform the synergy at NASA continue to be asked.

Dr. Hoeksema reiterated the need to discuss how the two groups' products will fit together so that writing the Strategic Roadmap will flow logically from the Foundation Roadmap and will prevent having to write everything twice. He added that in setting priorities, the Foundation Committee tried to keep the top-down structure to direct the order of its activities.

Dr. Killeen closed the morning session by noting that at the level of the RFAs, a more direct linkage needs to be established between the Objective and the technological dependencies inherent in seeking answers to particular questions; more must also be included about the effects on the *human* environment as a point of focus in particular objectives.

Lunch Presentation: Socio-Economic Impacts of Space Weather

R.A. Williamson, Space Policy Institute, G.W. University

Dr. Williamson's presentation outlined some of the major economic and social impacts of space weather and discussed particular effects on the electric energy grid in the United States.

Highly active regions on the Sun emit X-rays and high-energy particles that then interact in complex ways with Earth's atmosphere and magnetic field. The resulting interactions often adversely affect modern technological systems such as satellites, power lines, and high-frequency radio transmissions, causing economic loss and occasional social disruption. Geomagnetically Induced Currents (GICs) in transmission lines, for instance, can alter the AC current and cause cascading damages and outages to power systems in the United States and Canada. Systems in the high magnetic latitudes, such as the northern United States, Canada, Scandinavia, and Russia, are at particular risk because Earth's magnetic fields converge near the geographic poles, allowing energetic particles to reach low into the atmosphere. Increased concern about the growing vulnerability of the system makes getting early predictions key.

Dr. Williamson identified the Advanced Composition Explorer (ACE) and the Solar and Heliospheric Observatory (SOHO) as being two critical sensors, along with NOAA polar orbiters and GEOS satellites. He said models are being developed to make better use of space weather data, including the data's utility in discerning radiation effects on humans in space and in high atmospheres. How to go from research to applications/operations is a major issue, which GW helps to address by bringing together diverse groups within the space weather community for commingling and standardizing to the degree possible. It is a nonlinear process that demands knowing the data needed, how to integrate that data, the potential uses, and the end users. Action: Dr. Williamson will send his draft report to Barbara Giles for the Committee's review and input, if desired.

Education and Public Outreach

Rosamond Kinzler, American Museum of Natural History

Dr. Kinzler, representing the Educate Students and Public Roadmap 12, read from that charge, which reflects NASA's overarching goals for integration and cross-fertilization between Roadmaps.

Her presentation called for "unifying themes" and for public outreach information to be submitted in a themed, sustained way to educators and museums, including success stories. Uniform product lines with themed content is needed in order for schools, museums, and science centers to use them. A broad dissemination and demonstration of impact is desired and is too big a challenge to lay on researchers, requiring consideration of more global approaches. Further, resources must be applied for the longer haul to ensure, for example, that websites are regularly updated.

Dr. Killeen noted real education and public outreach opportunity in this field, given its strong visual content and the inclusion of magnetism as a subject area in school curricula, which opens the door for this Committee to more aggressively submit and urge inclusion of material. Dr. Kinzler reinforced the idea of mapping what NASA is doing to the curriculum of schools. Another member noted that the natural curiosity people have with regard to space provides a built-in PR/outreach device that museums want to plug into. All agreed that education and public outreach is a key area that requires focused funding and sustained efforts. This SSSC Strategic Roadmap Committee needs to work in tandem with the other Committees to formulate a broader education and public outreach effort—one that extends beyond K-12 education to the public as whole.

The SSSC community's goals of keeping astronauts safe and productive are important to the public, and should be promoted. The difficulty is determining what the product should look like and how a coherent strategy could be applied to translate and tailor it for the public. Perhaps, with the proper application of resources, a version of the Roadmap could be made accessible to the public. Public outreach is needed, too—outreach, not advertisement—as efforts have not gone far enough to keep the public informed. Workforce issues are another challenge in terms of promoting STEM (science, technology, engineering, and math) careers and present good opportunities for aligning with Roadmap language.

Dr. Kinzler's specific recommendations included the following:

- Focus on developing the workforce.
- Identify the unique education and public outreach opportunities for the Sun-Solar System science.
- Look at ways to replicate good models with different topic areas (e.g., planetaria with young people).
- [NASA needs to] gear resources to conduct education and public outreach in a sustained manner and with a sense of currency.
- Integrate cutting edge Sun-Earth system topics into undergraduate physics courses.
- Provide templates for Principal Investigators (PIs) to use for outreach efforts.

The SSSC Strategic Roadmap will need to develop an education and public outreach strategy and be able to thread it to Roadmap 12.

SSSC Capabilities, Facilities, Human Capital, and Infrastructure

James Slavin, NASA Goddard Space Flight Center

In describing that which is attainable in terms of NASA capabilities and facilities, Dr. Slavin began with a description of The Great Observatory and the SSSC Sensor Net in particular. This is a set of sensors that are all linked and that change what they do in response to a stimulus; it is how measurements are gathered. Dr. Slavin described The Great Observatory as a first-generation sensor net, which will become increasingly important as spacecraft are added and a new era of space exploration begun.

Many fast technological changes have taken place in how data are handed—from magnetic tapes to new web technology to a virtual observatory (VxO) concept. VxOs are intelligent websites that promise to be a boon to researchers and to improving the overall efficiency of processing and disseminating data.

How measurements are used is also changing and is moving increasingly toward studying the solar system as a linked system. The Center for Integrated Space-Weather Modeling is a large part of that movement, and CISM Institutions are now found in universities all across the country.

A Community Coordinated Modeling Center (CCMC), located at NASA Goddard Space Flight Center, arose out of an increasing need to interface with the operational community. CCMC is a multi-agency partnership of stakeholders formed a few years ago that, with CISM, accepts codes and models from the community. Guided by a board of directors, the group determines which models stand the best chance of being used by certain communities and which would be good for use downstream. In other words, they validate models and transition them to operational users, as well as provide access to running models for the space-research community to request "runs."

Dr. Slavin also spoke of human capital issues, calling them "key to everything we do." The three points that he continually hears from the community are:

1. Maintenance of a robust and vigorous science and technical workforce continues to be a challenge.
2. Instrument teams are thought to be especially "fragile" because they require phased instrument development (all TRL levels) and LCAS flight opportunities that culminate in the flagship missions.
3. Sounding rockets and Explorer missions are key to providing sufficiently frequent access to space to maintain an adequate pool of instrumentation scientists and engineers. (He added that it takes 20-30 years to create a mature scientist or engineer and maybe 1 year of no- or under-funding to lose them.)

Dr. Killeen noted that the SSSC Strategic Roadmap would likely need to have these issues embedded in it, including human capital. Action: James Slavin will devise a generic set of statements for how to build in everything covered in his presentation to facilitate the flow of information and knowledge.

Mr. Diaz observed that benefits associated with the Sun-Solar System discipline make it more compatible with recruiting people into the field, for while it does not have the current visibility of the planetary realm, its ease of access as a science should present an area to capitalize upon. The Sensor Net is out there, allowing much opportunity for hands-on interaction.

Dr. Fisher agreed that educational benefit and flow of human capital are strong rationales to include in the Roadmap, along with the science portion. Dr. Killeen added that cutting edge computational science aspects, such as data management, mass storage, and distribution systems, should also be included. Dr. Kletzing urged that project management be emphasized as well. Action: Combine what is currently available in terms of capabilities, facilities, human capital, and infrastructure with these discussions and with what has been covered already in the Foundation Roadmap. Information from some of the current detailed data tools might also be integrated here, so that "real physics" are included. Dr. Hoeksema will make sure this is covered in the Roadmap drafts.

Mission/Technology Studies

Bill Gibson, Southwest Research Institute

In his presentation, Mr. Gibson stressed the importance of eliciting outside industry involvement to ensure ample opportunity for feedback, "sanity" checks, and helpful input into studies before they become RFIs and RFPs. He observed the need to be more sensitive to the development of exploration requirements and to include those in mission studies, also stressing the importance of getting usable and immediately digestible information to the implementation people. He said value accrues from "putting a little more meat onto risk management," even at the early stages of mission studies. Using historical information and lessons learned can guard against continuing to do something that is systemically and consistently wrong. Action: Tom Moore and Bill Gibson will work together to map mission concepts to Roadmap elements and will have that product available at the next meeting. This will likely be a matrix that shows respective contributions to the decision system in terms of mission, products, and timeliness issues. A suggestion was made to review two previous Roadmaps.

Integration with Science and Capability Roadmaps

Azita Valinia, APIO Coordinator

Dr. Valina reviewed the NASA Strategic Roadmaps (SRM) and Capability Roadmaps (CRM) in parallel development, noting that from now until early April, all APIO coordinators will draft summaries of SRM-to-CRM relationships and SRM to SRM relationships, noting high-level interdependencies, which will serve as an appendix to the April 15 SSSC SRM draft that this group is producing.

Three modules (or subteams with a common goal) have been established, representing a "first cut" at dividing all Roadmaps into logical groups:

1. Scientific achievements (all RMs)
2. Expansion of robotic/human presence (Moon, Mars, Transportation, Nuclear)
3. Understanding space environment and effects on humans (ISS, SSSC, Moon)

All interdependencies will be used to create architectures, an assembly of program elements and major missions drawn from Roadmaps. Members of each module subteam will be APIO coordinators assigned to various Roadmaps. The SSSC Roadmap will have a presence on modules

1 and 3 (minimally). Committee members will forward their interdependency topics/questions to the integration subteam, who will address the issues with coordinators from other Roadmaps. The subteam will report on the status of the interdependencies appendix at the coming March meeting.

Dr. Valina exhibited the draft interdependencies appendix under way. Arrayed in a matrix format, the first column of the interdependencies matrix was labeled "Common Objective." One of these was "Sustainability of life in the universe." Committee members asked that "Mars and planetary science" be added to this cell, a suggestion accepted. Action: SSSC Committee members will iterate on the current text that the subteam is working with, expanding on current topic descriptions. Michelle Thomsen will be the group's representative in this regard, and Todd Hoeksema will appoint members of his Foundation Roadmap Committee to also serve on the integration subteam for each of the "Common Objective" areas currently displayed in the interdependencies matrix.

Richard Barney, GSFC, Science Instruments and Sensors Capability Roadmap

Mr. Barney said the Science Instrument and Sensor Roadmaps define critical capabilities focused on science and aimed at answering compelling science questions associated with the vision for space exploration. The process involves looking at the full range of scientific instruments.

Mr. Diaz observed the need to have diverse and broad input sources to ensure needed integration and potential multiple uses. Mr. Barney responded that his group is collecting input from all the Roadmaps and making sure that all are "reading from the same sheet of music." The product of the group will be a Roadmap with a timeline out to 2030 showing the missions that are driving capability development, including long-lifetime lasers, capabilities, and decision points. Action: James Slavin will ensure that his community has input into the draft capability paper. He will forward the SSSC Imaging Workshop (Jim Spann, NASA MSFC) white paper to Mr. Barney. Capability Roadmap teams have many documents on the agency's Docushare that people may access. Mr. Barney may be contacted by email at Rich.barney@nasa.gov.

Mr. Barney noted that one way mitigate parallel development concerns is to begin the integration process early. He said Capability teams are fully prepared to absorb the SSSC Strategic Roadmap Committee's content whenever it becomes available, likely in April; therefore, the document should specify particular technologies of value. Mr. Diaz commented that the SSSC Strategic Roadmap should also be accompanied by an investment strategy, or it will not be accomplished. Mr. Barney said his group hopes to use the new approach to get technologies through.

Conclusion

The SSSC Strategic Roadmap Committee is considering a three-part approach to address NASA Strategic Objective 15:

1. Characterize our home in space
2. Safeguard our outbound journey
3. Build our knowledge system of the space environment

Strands of transformational and applied science are entwined in this community, which would seek to successfully build a knowledge system that allows a full-blown predictive capability for the Sun-Solar System—a 30-year perspective that builds on the IT revolution and the instrumentation capability that NASA brings to the table.

Mr. Diaz suggested that the group review the approach taken by Roadmap 9, specifically:

1. Explore frontiers of science (integration of biological processes, what defines the frontier, follow the water, follow the energy, etc.)
2. Continual Awareness (what are the critical problems?)
3. Maintain Perspective (the sustaining of long-term data sets and observations)

Roadmap 9 also incorporated decision support, or ways to react for the future. Both Roadmaps have chosen to be more applied than in the past and geared more toward predictability. Both groups have also chosen to be more dynamic as well, embracing a new approach in lieu of traditional approaches that say “we’re looking for life on Mars.” The question, observed Mr. Diaz, is whether space weather is predictable. Dr. Killeen responded that the Committee intends to look at ensemble models, probabilities outcome, data injection schemes, etc., calling these analogous to the historical development of Earth weather predictive systems.

The meeting ended at 4:50 pm.

Appendix A—Committee Member Contact Information

SRC # 10 - Sun-Solar System Connection Strategic Roadmap Committee		
Name	**Affiliation**	**Fed Ex Mailing Address**
Co-Chairs		
Mr. Al Diaz	NASA HQ, Associate Administrator/Science Mission Directorate	
Dr. Franco Einaudi	NASA GSFC	Code 610 Bldg. 33, Rm. E122 Greenbelt, MD 20771
Dr. Timothy Killeen	National Center for Atmospheric Research	1850 Table Mesa Dr. Boulder, CO 80305
NASA/Government		
Dr. Edward Lu	NASA/JSC	Code CB 2101 NASA Road 1 Houston, TX 77058
Dr. James A. Slavin	NASA/GSFC	Code 696/Bldg 21/Room 222 Greenbelt, MD 20771
Dr. Warren Wiscombe	NASA/GSFC	Mailstop 913.0 Greenbelt, MD 20771
Dr. Victor Pizzo	NOAA Space Environment Center	325 Broadway Boulder, CO 80305
Dr. Michelle Thomsen	Los Alamos National Laboratory	SM-30, Bikini Atoll Road MS D466 Los Alamos, NM 87545
Academia		
Dr. James M. Russell III	Hampton University, Center for Atmospheric Sciences	23 Tyler Street Hampton, VA 23668
Prof. Jeffrey M. Forbes	University of Colorado, Aerospace Engineering Sciences Department	429 UCB Engineering Center ECOT-634 Boulder, CO 80309-0429
Dr. Craig Kletzing	University of Iowa, Dept Physics & Astronomy, Associate Professor and Associate Chair	Rm 203 Van Allen Hall Iowa City, IA 52242
Dr. J. Todd Hoeksema	Stanford University	HEPL Annex B 455 Via Palou Stanford, CA 94305-4085
Dr. A. Scott Denning	Colorado State University, Department of Atmospheric Science	200 West Lake Street Fort Collins, CO 80523

SRC # 10 - Sun-Solar System Connection Strategic Roadmap Committee		
Name	**Affiliation**	**Fed Ex Mailing Address**
Industry		
Dr. Stephen Fuselier	Lockheed Martin Advanced Technology Center	Dept. ADCS, Bldg 255 3251 Hanover St. Palo Alto, CA 94304
Dr. Donald M. Hassler	Southwest Research Institute	1050 Walnut St Suite 400 Boulder, CO 80302
Mr. William C. Gibson	Southwest Research Institute, Assistant Vice President	6220 Culebra Road P. O. Drawer 28510 San Antonio Texas 78228-0510
Ex Officio Members		
Dr. Richard Fisher	NASA HQ	
Dr. Donald Anderson	NASA HQ	
Dr. Michael Wargo	NASA HQ	
Mr. Mark Weyland	NASA/JSC, Radiation Analysis Group	
Systems Engineers		
Mr. Tim Van Sant	NASA/GSFC	
Mr. John Azzolini	NASA/GSFC	
APIO Coordinator		
Dr. Azita Valinia	NASA/GSFC	
Directorate Coordinator		
Dr. Barbara Giles	NASA/GSFC	
Education Specialist		
Dr. Rosamond Kinzler	American Museum of Natural History, Director, The National Center for Science Literacy, Education and Technology Department of Education	Central Park West at 79th Street New York, NY 10024-5192
National Security Space Representatives		
Mr. Alan Shaffer	National Security Space liaison, Office of the Secretary of Defense	

Appendix B—Agendas for Sun-Solar System Connection Roadmap Committee

Day 1, February 10, 2005, NASA HQ
Location: HQ MIC6 (6H65)

0800	Auditorium open, coffee in the lobby	
0830	Welcome, introduction of Committee, ex-officio and liaison members	Co-chairs: Al Diaz, Franco Einaudi and Tim Killeen
0840	Co-chair Introductory Remarks (~5-10 min each)	Co-chairs: Al Diaz, Franco Einaudi and Tim Killeen
0900	NASA Strategic Planning, charge to the Committee	Marc Allen
1000	Break	
1010	State of the theme: Sun-Solar System Connection	Richard Fisher
1100	SSSC Foundation Roadmap Science	Todd Hoeksema
1130	Technology and Mission Study Process and Status	Thomas Moore
1200	Pick up Lunch, back to the meeting room for a Science Presentation: Stan Solomon, *National Center for Atmospheric Research, High Altitude Observatory on the Development of Modeling Frameworks for the Sun-Solar System Connection*	
1300	FACA briefing to the Committee	Diane Rausch
1315	NASA ethics briefing to the Committee	Rebecca Gilchrist
1400	Step-back: Context-setting discussion	Co-chairs to lead discussion
1500	Break	
1515	Identification of Sun–Earth integrating science questions: Connections to Earth Science	Scott Denning and Warrne Wiscombe to lead discussion
1600	Human Flight Space Weather	Mark Weyland to lead discussion
1630	Operational Space Weather	Victor Pizzo to lead discussion
1700	Discussion, overnight assignments	Co-chairs
1730	Adjourn	
1830	Group Dinner at TBD restaurant	

Day 2, February 11, 2005, NASA HQ

Location: HQ MIC6 (6H65)

0815	Meeting Room Open, Coffee	
0830	Welcome, organization issues	Al Diaz
0845	Round Table Discussion – Science and Vision (each member to comment, ~ 5min each)	Committee
0945	Transformational Sun-Solar System Connection Science	Michelle Thomsen to lead discussion
1015	Break	
1030	Roadmap Science Objective #1, scope, focus areas	Craig Kletzing
1045	Roadmap Science Objective #2, scope, focus areas	Don Hassler
1100	Roadmap Science Objective #3, scope, focus areas	Jeff Forbes
1115	Discussion on the roadmap objectives Committee	
1200	Pick up Lunch, back to the meeting room for a Science Presentation: Ray Williamson*, Space Policy Institute, George Washington Univ. on The Socio-Economic Impacts of Space Weather*	
1300	Education and public outreach Plans	Rosamond Kinzler to lead discussion
1345	Capabilities, facilities, human capital, infrastructure	Jim Slavin to lead discussion
1415	Mission/technology studies	Bill Gibson to lead discussion
1445	Integration with Science and Capability Roadmaps	Azita Valinia to lead
1515	Break	
1530	Discussion	Committee
1630	Closing remarks, assignments	Co-chairs
1700	Adjourn	
END OF MEETING		